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FROM A SURGEON'S JOURNAL

I. The Harvard Unit and the Ambulance Américaine

BY HARVEY CUSHING

[In August 1914, a group of Americans resident in Paris undertook the organization of a military hospital and ambulance service. The French Government put at their disposal a newly erected school building, the Lycée Pasteur, which was altered and equipped to provide for some six hundred patients. Certain universities in the States were then asked to participate in the project by successively supplying the professional personnel capable of caring for a certain number of wounded for a three months' period. The first of these units, from Western Reserve University, under the direction of Dr. Crile, began its term of service in January 1915. A Harvard unit, financed by Mr. William Lindsey of Boston, followed in April 1915. — The Editors]

Thursday, March 18, 1915

She seemed very low in the water — the *Canopic* — when we found her hidden behind the new Commonwealth Pier yesterday afternoon, with two interned Hamburg-American ships on the opposite side. Strange company! And when, after our false start at 4.15, we returned again at eight for the sailing, she was still lower. Ammunition for the Allies, it is said. What a temptation it must have been to *die Leute* across the dock! A stowaway with a bomb would do it — and there seemed to be no precautions such as one would perhaps expect on an English ship under existing circumstances.

It was a cold blowy March night by the time our pilot was dropped outside of Boston Light, and though the merry-makers, Benet and Barton, marched the decks with tin flutes tuned to 'Tipperary,' blue noses soon drove us in and to bed.

There are only fifty first-cabin passengers, seventeen of them constituting our immediate party, to which three or four others are *c'est à dire* allied. So there's plenty of room, though no place to go but out, and no place to stay but in — with one's overcoat on in either case.

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STREAMLINING

BY NORMAN BEL GEDDES

I

ORIGINALLY, the word 'streamline' was a term of hydrodynamics. About the year 1909 the science of aerodynamics borrowed it to describe smooth flow of air as well as the form of a body which would move through air with a minimum of resistance. For some years 'streamline' in its aerodynamic sense enjoyed honorable obscurity in the physics laboratory and the shop talk of engineers. Last year, however, advertising copy writers seized upon it as a handy synonym for the word 'new,' using it indiscriminately and often inexactly to describe automobiles and women's dresses, railroad trains and men's shoes. Into such general use has the word come that it is, perhaps, time to examine its meaning and its implications.

The truth of the matter is that very little is known about streamlining. Most of the popular explanations have treated it as though the facts were established and accepted, and in this respect some technical treatises have not been without fault. Streamlining as a science has not yet really been born. Its practical development in aeronautics has been highly effective, but not understood. In other fields, both in theory and in practice, it is still in embryo.

Even the assumptions upon which the science is based elude proof and have neither been demonstrated nor been clearly visualized. In 1755 Leonhard Euler devised three monumental equations for the flow of an ideal fluid — one which has neither compressibility nor viscosity. He was thinking in terms of liquids, but his work applied to air as well. The equations assumed that fluid flow was a *continuation of particles.* It is worth noting that even to this day no one has accurately pictured what air particles consist of, or how they act. Nevertheless, the Eulerian assumption and equations form the backbone of modern streamline thought.

To understand how there can be value in an assumption which cannot be visualized and an equation for an ideal substance which does not exist, it is necessary to appreciate the distinctions between mathematician, physicist, and engineer. The mathematician is less concerned with the correctness of assumptions than with the mathematical structure erected upon them. The physicist, on the other hand, is interested in the correctness of assumptions, for he must connect the mathematician's equation with what actually happens in the physical world. The engineer, finally, takes the equation, substitutes the physical quantities determined by the physicist, and emerges with a practical solution. The physicist and engineer, since their theory must spring from present knowledge, can advance but one step at a time. The mathematician, however,

in the wind tunnel, thereby considerably improving the state of mind of the pilot who made the first test flight.

There are still gaps in the knowledge of fluid flow, even about a body in free flight, which will probably not be closed until it is possible to approach the problem from pure theory. A large airplane completed this year was calculated to have a maximum speed of 165 miles per hour. In actual flight, however, it flew at 192 miles per hour. The difference between the computations and the facts has not been explained in this and many similar cases. Another indication of our ignorance of the flow of air appeared in a recent tunnel test when a wind of 500 miles per hour acted on a standard wing section whose characteristics were fairly well accepted. The boundary layer broke sharply away in streamers at right angles to the surface. There is a euphonious name for this conduct, — *compressibility burble*, — but the cause of it is unknown.

In spite of the hiatus here and there in the theory, parasite drag in the airplane has been eliminated to an amazing degree by the empirical method, and airplane streamlining can be considered to be approaching practical perfection. In 1918 a 400-horsepower motor drove a plane at 125 miles per hour. To-day the equivalent power in a comparable plane would produce a speed of perhaps 200 miles per hour.

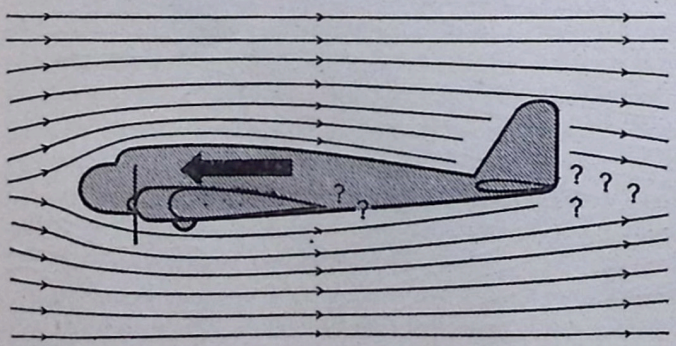

Fig. 3 — Airplane streamlining is very effective. There are few places where the flow pattern is uncertain

III

In the scientific sense, streamlining, so highly developed in the airplane, has made but little progress in the motor car, the railroad train, and the steamship, all of which stand to gain in efficiency, riding comfort, and economy when drag is reduced. Though streamline attempts have been made in several trains and motor cars, their influence on drag is open to question. In the American mass-production automotive field, only the Chrysler and De Soto can be considered as pointing toward authentic streamline form. Nevertheless the significance of these two cars lies not in their streamline efficiency but in the foresight and courage shown by Walter P. Chrysler in departing abruptly from traditional attitudes of appearance. What the scientifically streamlined automobile will look like can merely be assumed within fairly broad limits, but it will certainly bear little resemblance to the car of to-day. The weaning of public taste from its illogical prejudices in the matter of appearance is paving the way for whatever form will best meet the automobile's requirements.

It has become fashionable of late to predict what streamlining will do for the motor car and the train. Unusually high speeds have been foreseen and practically no fuel consumption at all. While it is perfectly reasonable to expect a great deal from streamlining, the fact remains that its possibilities in the automobile and the train have been viewed through glasses made rose-color by the experience of aeronautics. Because of two factors not encountered in the free flight of an airplane, present knowledge does not assure us that the airplane's great success in

overcoming parasite drag will be easily repeated in a vehicle moving in contact with the ground. These two factors are *ground effect* and *cross winds*.

The flying airplane is emersed in a fluid the flow characteristics of which are virtually identical on all sides (Figure 3). Were it not for the force of gravity, the plane would perform equally well right side up, upside down, and on its side. The automobile, however, because of the presence of the ground, cannot be assumed to have identical flow characteristics on all sides (Figure 4). Consequently the available streamline data for the airplane cannot be regarded as accurate for the car. Since the nature of ground effect is as mysterious as most other aerodynamic conditions, the automotive engineer must take the long slow road of laboratory experimentation if he is to arrive at highly effective streamline forms.

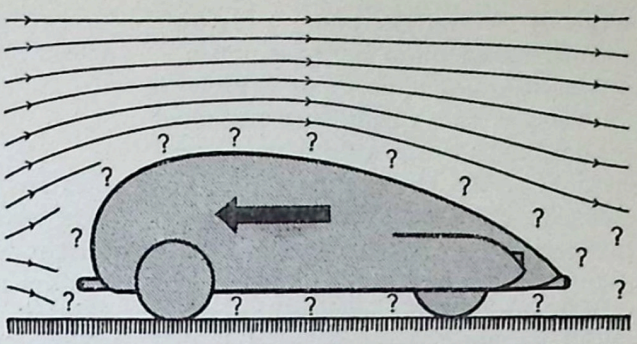

Fig. 4 — The ground effect makes the flow pattern around a motor car a matter of conjecture at best

Unfortunately, actual experimentation cannot begin until practical, accurate methods and apparatus are developed. The means at present available for the study of ground effect are not satisfactory. Outdoor tests with full-scale models are complicated by variations in wind and road conditions. Small-scale wind tunnels have been used with running belts or revolving disks to simulate a road moving under the wheels. But the belts have flapped the stream of air into chaos, and the disks have failed to represent road conditions with the necessary accuracy. There is need for a representative road surface which can be run at high speed without flutter, and with a new treatment of the test chamber to reproduce road performance. This tunnel should also permit both the surface and the model to be turned at an angle to the wind, for car streamlining will not flower from knowledge of ground effect alone. There is, in addition, the matter of cross winds to be considered.

To the flying airplane, aerodynamically speaking, there is no such thing as a cross wind (Figure 5). This is a fact and not an opinion, and yet a great many people insist on arguing the point. To visualize why a cross wind does not affect the flow pattern around an airplane, imagine a dirigible floating above the earth with its motors stopped. If there is wind, relative to the ground, the dirigible will drift in the wind's direction and at its speed. The air, relative to the dirigible, will be motionless, and a man putting his hand out a gondola window will feel no wind whatsoever. If, now, the motors are started, the dirigible will head directly into the air, just as though it were starting from the ground on a day when there was no wind at all.

Substitute an airplane for the dirigible and the conditions are unchanged. From the time the plane's wheels leave the ground until they touch again, cross winds do not exist as an aerodynamic factor. It is well known that an airplane takes off and lands into the wind. This eliminates the cross effect while the wheels are in contact with the ground. The wheels of the plane landing in air which is moving at forty miles an hour across the runway would

suddenly anchor the plane and cause a ground loop and a probable crash.

The automobile does not drift with the wind as an airplane does and must contend with cross wind a great proportion of the time (Figure 6). The fact that the average wind velocity in this country is estimated at not more than ten miles per hour has been offered as evidence that cross winds are not important. However, a cross wind of even such low velocity, acting at right

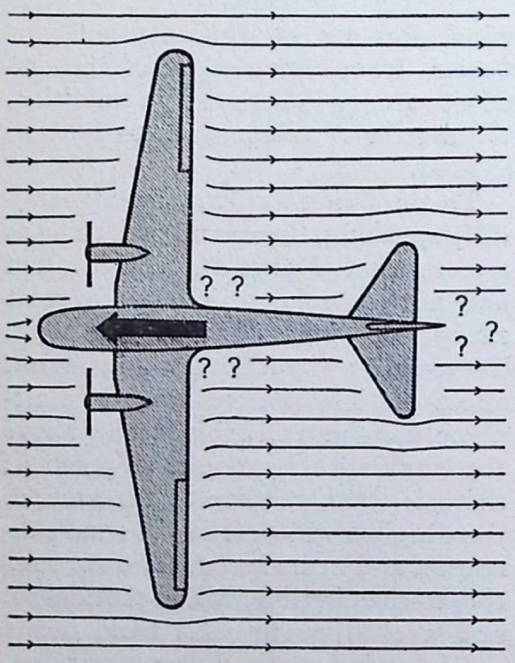

Fig. 5 — The airplane *always* meets the air directly head-on

angles to the road, might destroy a considerable part of the body's streamline efficiency because of the altered flow pattern of the air. The forms which are effective for the airplane will not, therefore, suffice for the motor car, and new forms must be developed. Cross winds, moreover, affect stability as well as parasite drag. Comparatively low velocities can impair the accuracy of steering, and high winds find little difficulty in blowing a car entirely off the road. By reducing the resistance offered to cross winds the car's stability would be increased, provided that the location of the centre of pressure were within the necessary limits.

IV

From the technical point of view, then, streamlining of the motor car must reduce resistance to the air, both head-on and from the side, and must maintain present stability or improve it. The first and simplest step, and the one which is now under way, is the elimination of protuberances — headlights, fenders, door hinges, spare tires. Clean continuous lines from front to rear would aid in reaching all the objectives. The second and certainly equally important step is the development of the form. It is probable that this form will be a compromise, for it is extremely unlikely that any single solution can ideally satisfy all requirements. More than that cannot intelligently be said at the present time, nor can the form be foretold until the advent of sound data specific to the motor car, or until theory becomes more complete.

The technical requirements are not the only ones, however, and it is to be expected that further compromises will be necessary to provide convenience and comfort — two factors that are becoming increasingly important as the car ceases to be an article of sporting equipment and takes its place with the stove and the toothbrush as a normal commodity. It is likely that part of the problem will be to see how much space can be afforded the passengers, and, conceivably, the public will come to demand some of the roominess and comfort that are enjoyed in a small room of a home. At the same time, broad visibility and ease of riding, driving, and parking will have to be provided. Streamlining will decrease the noise caused by undirected flow of air and will result in a more quiet ride.

The logical development of the

streamline car will probably mean the placement of the motor in the rear. The space in a tapered rear could be used to better advantage to house the engine than for other purposes, and the front end, the largest part of the body, would be released for driver and passenger accommodations. There are several technical disputes to be adjusted before the rear-engined car becomes a frequent sight on our roads, but no insurmountable obstacle seems to exist. In Europe at the present time there are several manufacturers offering cars of this type.

While a perfect streamline form would add a somewhat greater top speed to the performance of an automobile to-day, greater speed is not the goal of the car as it is of the airplane. Practically all recent cars can attain a speed of seventy miles per hour, which is quite fast enough under present conditions for all but a rare driver on an even rarer stretch of perfect road. The object of reducing air resistance is to increase efficiency and economy of operation, and while streamlining can make this possible, it cannot, unassisted, accomplish it.

A conventional car, equipped with a streamlined body offering virtually no resistance to air, would require less than half the power formerly needed to drive it at fifty miles per hour. Yet gasoline consumption would by no means be halved, for the engine would be operating inefficiently. Greater economy would come from halving the size of the motor, but with half the power, ample for level running, the car would be sluggish to accelerate and climb hills.

Accelerating and hill-climbing ability is determined by the ratio of effective power to weight and is only slightly affected by air resistance. If the car weight were reduced by half, the smaller motor would produce the same pick-up and hill-climbing performance as the larger motor in the heavier car. But the lighter car, with present-day springs and tires, would probably skid more easily, bounce uncomfortably on a rough road, and be more at the mercy of cross winds. Nevertheless, smaller motors are essential to the realization of the benefits of streamlining, and they can be used in even heavy cars when the present fixed-ratio transmission is replaced by a means that will

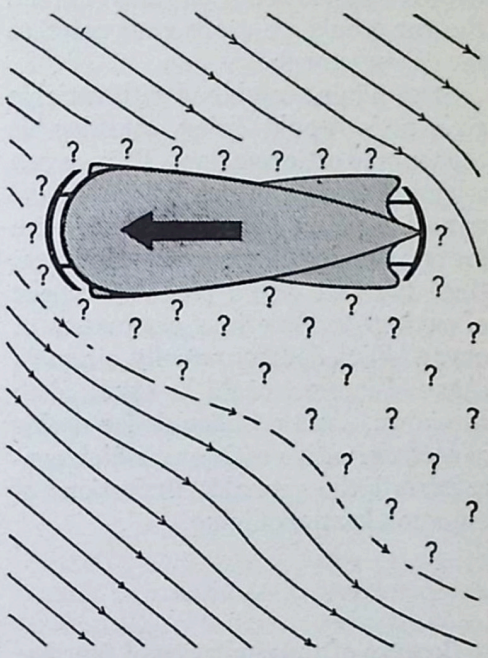

Fig. 6 — Motor-car streamlining is complicated by cross winds

give a continuously variable gear ratio between motor and wheels.

It is an idiosyncrasy of every internal-combustion engine that it delivers a different amount of power at each speed. In high gear, a motor developing forty-five horsepower at a sixty-mile-an-hour car speed may produce less than twenty horsepower at a twenty-mile-an-hour car speed. With existing transmissions, too little power is available at low car speeds in high gear, and too much at high speeds. The variable gear ratio would permit the motor to run at the lowest rate at which the necessary power could be

smoothly applied to the wheels, a condition which would reduce oil and gasoline consumption and engine wear. The same variable gear ratio, with a different setting, would provide maximum vitality for acceleration and hill climbing by making it possible to apply the full horsepower of the motor to the wheels regardless of the speed of the car. In spite of the decreased maximum power of the smaller motor, greater effective power could be called on and the car would be more responsive to the driver's touch.

Streamlining combined with variable gear ratio would bring considerable economy to car operation. There is one school of thought which holds that the motoring public is not concerned with lower running expenses. However, since the bait would probably consist of savings to American car owners of over a billion dollars annually, a certain spark of interest could be expected to be shown. And a billion-dollar saving is a conservative estimate, which considers all the probable limitations of automobile streamlining.

V

Because of the similarity of function between the automobile and the bus, any development which reduces parasite drag in one will be applicable in some degree to the other. As a matter of fact, the bus will perhaps use streamlining the more advantageously, for decreased drag brings its greatest reward during sustained running, which is more often the function of the bus than of the automobile. Moreover, the dimensions of the bus offer greater latitude for the development of a form to which the boundary layer will have an affinity. Consequently air resistance may be more effectively overcome. The bus already has at its disposal a variable gear ratio in the Diesel-electric drive, which is too expensive and too heavy for use in the passenger automobile. Even if the advantages of streamlining the bus are not actually greater, they will probably be achieved sooner.

Most of the problems of streamlining the car and the bus will also have to be solved for the railroad train. The importance of parasite drag in this field of transportation can be appreciated from the fact that air resistance is often sufficient to demand a reduction in tonnage. At times it is great enough to stall a train. In view of the publicity attending the appearance of recent trains that bid for streamline honors, it should be remarked that streamlining and the railroad train are old friends. As far back as 1847, Bessemer ran tests on the air resistance of trains at various speeds. A locomotive with streamline tendencies was exhibited at the St. Louis World's Fair in 1876. That and the 'Wind-splitter' of the eighteen-nineties were two of the earliest-known attempts to modify the form of any vehicle with regard for air resistance.

Some of the present streamline trains have done three things toward lessening resistance. They have faired-in the articulated joints, and the continuous surfaces thus produced have helped to decrease one cause of turbulence. They have decreased the projected frontal area to which air resistance is proportional. And to some extent they have tapered the rear end of the last car. It is doubtful, however, if streamline efficiency is high.

Development of a proper streamline form for the train will require special data accumulated in the same kind of wind tunnel in which the motor car and bus would be studied. It is unlikely, however, that the train will ever conquer parasite drag to the same degree as other land vehicles. Just as the dimensions of the bus are more adaptable to streamline purposes than those of the

car, the dimensions of the train are less so than either. The comparatively great length and narrow width of the train require long flat surfaces which are not conducive to control of the boundary layer.

In spite of the uncertain effectiveness of present train streamlining, operating efficiency has been improved by a reduction of weight resulting from the use of new materials and structural methods. On the *monocoque* principle of construction, the outer shell has been designed to act as a structural member, sharing the stresses with the beams. Smaller beams have been used, and, since they are made of light new materials, their weights have been but a fraction of those common in railroad practice. Because conventional trains weigh far more than is necessary for traction and braking power, the performance has not been adversely affected, although what would happen to one of these light trains in a collision has been the subject of speculation. With decreased weight, less power has been needed and a Diesel-electric drive has delivered it for less money, at the same time maintaining the variable ratio between engine and wheels provided by the steam engine.

VI

Of all transportation means the steamship has been the least responsive to the prospects for greater speed and economy of operation which can be gained from a decrease of air resistance. There exists a general attitude on the part of the operators that, since air drag is a small proportion of the ship's total resistance, it is not worth worrying about. So negligible was the effect of wind thought to be that until the last few years speed trials, most accurately conducted in other respects, practically disregarded the wind conditions prevailing at the time of test. Runs were made in two directions on the supposition that the effects of wind would cancel out. However, a ship at twenty knots, with a following wind of twenty knots, shows a speed increase equivalent to an increase of power of 2 to 4 per cent over the speed in still air. Heading into the same wind, the power loss may be as much as 16 per cent. Obviously the average tells a false story.

It is difficult to understand why the factor of air resistance should be snubbed when the speed rivalry between ships is so intense and so much money is spent for larger engines and more fuel in efforts to win blue pennants for ocean crossings. Ships, like airplanes, are tested in model form to determine full-size performance. The tests are usually made in water tanks and are concerned only with water resistance, stability, and manœuvrability. Actual performance, however, varies considerably from the results of the tank tests, presumably because of the direct and indirect effects of air resistance. In one study of a large number of transatlantic crossings, the average increase of resistance at a given speed, compared with tank predictions, was 30 per cent east-bound and 100 per cent west-bound. The greater west-bound variation seems to have been caused by the normally greater westerly winds and consequently heavier seas. These figures would certainly seem to warrant more respect for the resistance of air.

Except when a large ocean liner meets the wind directly head-on, it presents a larger resisting surface to the air than the total useful sail area which drove a clipper ship. In addition, the form of the hull above the water line and the irregularities of the superstructure promote turbulence of tremendous magnitude (Figure 7). Wind striking a conventional liner is made turbulent by every rivet, overlap, and porthole.

It climbs on deck and swirls around ventilators, towing bitts, hoists, lifeboats, davits, and life-belt boxes. It eddies around the wings of the bridge, the masts, the funnels. Were it possible to photograph the path of air passing over a ship, it would surely resemble a tangled skein of yarn.

Streamlining of the ship will require first of all a unified superstructure with smooth contours that will tend to maintain the contact of the boundary layer. The boundary layer of a ship is approximately one foot thick, and it may seem facetious to be talking about its importance to an object as large as an ocean liner, but our only tenable streamline theory demands it. After all, the importance of the boundary layer is no more incomprehensible than the fact that a ship as large as a skyscraper and weighing approximately as much can be rolled to the serious discomfort of the passengers by a ten-foot wave.

Elimination of protuberances on the superstructure is a refinement of design which can be predicted with certainty. In combating high winds an entirely enclosed superstructure would be desirable for speed, comfort, and safety. In calm weather, when the air resistance would be a good deal less and maximum streamline efficiency not quite so important, the skin enclosing play and promenade decks could be opened.

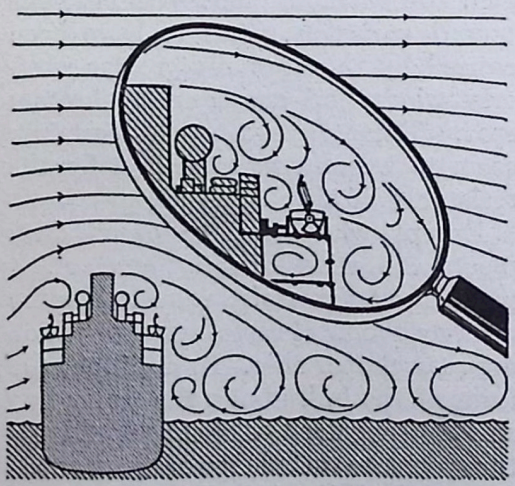

Fig. 7 — The superstructure of a ship causes turbulence of great magnitude with appreciable loss of power

The proper streamline form of the superstructure as a whole, however, is most indefinite. During the time that streamlining has been kept waiting in the outer offices of the steamship companies, naval engineers have been determining the various problems with which it must cope. Their data have shown that the ship's problem combines the peculiarities of the airplane and the automobile and confuses them by a few of its own. The ship, like the motor car and the train, must contend with ground — or more correctly *water* — effect, and yet, because of the great height of the superstructure, it is probable that disturbance in the flow pattern of the air caused by water effect or action of waves becomes negligible as the air passes over the mammoth form of the ship.

The chief factor in ship streamlining is the cross wind. In the last four years it has been determined that a ship offers the greatest resistance to air when the resultant of the cross wind and the head wind created by the forward motion of the ship is about thirty degrees off the bow. A 50 per cent greater resistance may be encountered than when an equal wind is directly on the bow. This is a direct result of the larger area presented to the wind, and a more turbulent flow pattern.

There are indirect results of cross wind which further decrease the efficiency of the ship (Figure 8). In a cross wind, the motor car and the railroad train, being held to a straight path by the traction of the wheels on the road or rails, have only a *tendency* to drift. The ship, on the other hand, being in a fluid medium, has an *actual* drift. If the ship is to be held to its course it must be turned into the wind somewhat to compensate for the drift. An angle of yaw is created whose influence

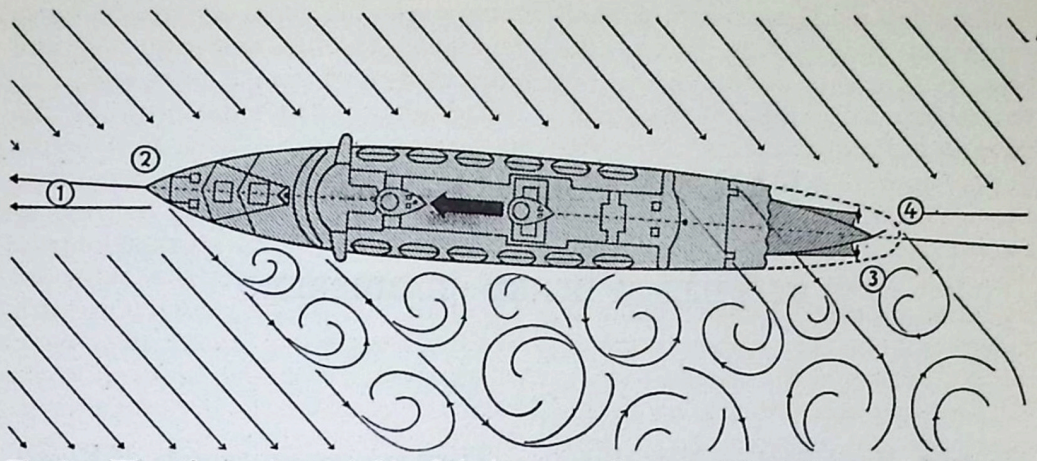

Fig. 8 — When the resultant wind is off the bow, power losses result from (1) yaw; (2) direct form resistance; (3) reduced propeller efficiency; (4) rudder resistance

on efficiency has recently been the subject of a study in England.

The yaw tends to force the ship through the water sideways — a difficult task at best. It requires that the rudder be carried continuously on the weather side — toward the direction from which the wind is blowing. This greatly increases the water resistance which the engines must overcome. At the same time the yaw causes the propellers to act at an angle to the direction of the ship's motion, and their efficiency is impaired.

It is dangerous to venture a prediction on the increased speed or fuel economy which may come from superstructure streamlining. We are more fully aware of the difficulties of the problem than of the benefits that are possible or the precise means of obtaining them. But it can safely be said that a fast transatlantic ship which cuts down head resistance and resistance to cross winds, thereby minimizing the losses which now spring from yaw, may be counted on to gain 8 per cent in speed. If it should choose to convert the higher efficiency into savings at slightly lower speeds, these might run as high as one fifth.

In addition to better performance there would probably also be an increase in carrying capacity. Since the likely streamlined form of the superstructure would tend to be more tubular in a section than square as at present, the advantages of *monocoque* construction might well be turned to account. This would mean lighter and less expensive ships, greater cargo tonnage, and greater strength for bad going.

As the speed of ocean traffic becomes greater, the advantages of streamlining the superstructure will be more evident. The three-day crossing of the Atlantic is perfectly feasible. But it would be foolhardy to attempt it without first designing a ship which would encourage friendly behavior on the part of three thousand miles of boundary layer. Exactly how the boundary layer will be tamed is something to think about.

No one can say when the science of streamlining will pass the prenatal stage of organization and orientation. There is a long road but a bright horizon ahead of it. In 1894 Octave Chanute wrote as follows: 'Science has been awaiting the great physicist, who, like Galileo or Newton, should bring order out of chaos in aerodynamics, and reduce its many anomalies to harmonious law.' In spite of all that has happened since 1894, especially to the airplane, the science of aerodynamics, and streamlining in particular, are still awaiting the same great scientist.